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High-Rate Mechanical Response and SEM Morphology of EX99 Gun Propellants

by Michael G. Leadore and Robert J. Lieb

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High-Rate Mechanical Response and SEM Morphology of EX99 Gun Propellants

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Abstract

Two lots of EX99 gun propellants from the Naval Surface Warfare Center (NSWC) were tested in uniaxial compression to an end strain of ~60%. The materials were preconditioned at test temperatures of 21°, 50°, and –20 °C while at ambient pressure. The stress at failure, strain at failure, compressive modulus, failure modulus, incremental energy density (IED), and the fracture assessment values (FAV) were recorded for each test. These materials were also evaluated for microstructure using a scanning electron microscope (SEM).

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1. Introduction

The U.S. Army Research Laboratory (ARL) conducted the material test systems (MTS) servo-hydraulic tester (SHT) high-rate mechanical response of two lots of Naval Surface Warfare Center (NSWC)-manufactured high-energy gun propellants. The materials were designated EX99 by the NSWC and given lot numbers of IH94000EEX99-0088 and IH23099DEX99-FB01. The lots were candidate propellants for the Abrams M829E3 120-mm tank gun round (Figure 1). (Test sets 01-06/Fiscal 01.)

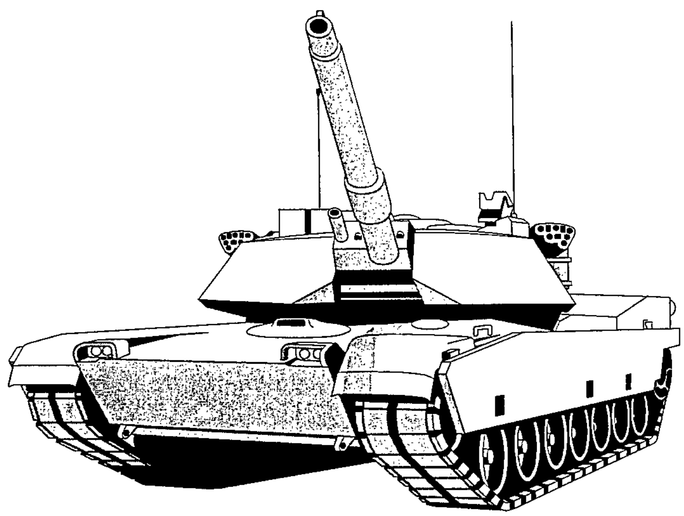

Figure 1. M1 Abrams tank with 120-mm gun.

2. Background

ARL received two lots of NSWC-manufactured gun propellants and testing instructions from Mr. Richard Muscato of the NSWC. The gun propellants were manufactured as 7-perforated granular propellants with diameters of ~10.0 mm for lot 0088 and ~11.7 mm for lot FB01. The perforations for both lots measured ~0.38 mm. Several grains from the lots of the experimental gun propellants were shipped to Dr. Robert Lieb of ARL. Also, a lot of similar material recently tested (September 2000) is included in the Appendix as well as the mechanical properties (Table A-1), stress vs. strain plot (Figure A-1), and photo (Figure A-2) of the tested material which may be used for comparative purposes as the test

conditions were similar. The lots of subject material were last tested for high-rate compressive mechanical response evaluation in October 2000.

3. Approach and Results

The propellants EX-99 lot numbers FB01 and 0088 were received in granular form with 7-perforations. The materials were prepared into test specimens using an Isomet double-bladed diamond saw and the sample ends were cut flat and square. The prepared test specimens (Figure 2) had an average length to diameter (L/D) of 1.04.

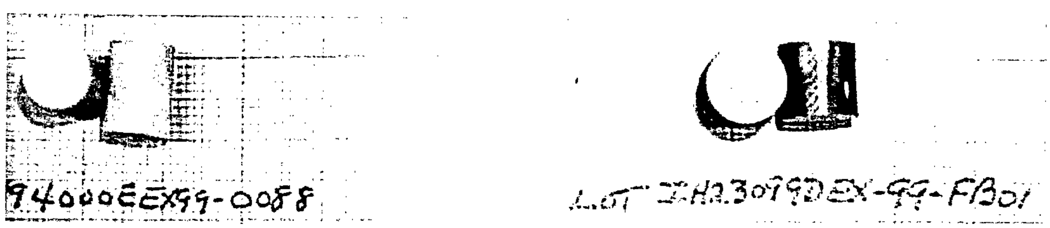

Figure 2. Prepared test specimens.

MTS SHT mechanical properties tests [1–7] were conducted on several specimens under each test condition (Figure 3). Strain rates of 122.6^{-s} were achieved. The specimens were taken to failure at ambient pressure to ~60% end strain while conditioned at 21°, 50°, and –20 °C. The stress at failure, strain at failure, modulus, failure modulus, incremental energy density, and fracture assessment value were recorded for each test. The average values achieved from the tests are listed in Table 1.

4. Conclusions

Two lots of NSWC-manufactured EX99 7-perforated gun propellants were tested in uniaxial compression at an average 1.31 m/s deformation rate. The materials were taken to ~60% end strain while conditioned at 21°, 50°, and –20 C. A lot of similar material tested using like conditions is included in the Appendix (Table A-1, Figures A-1 and A-2). This information may be used for comparative purposes as similar test conditions are used.

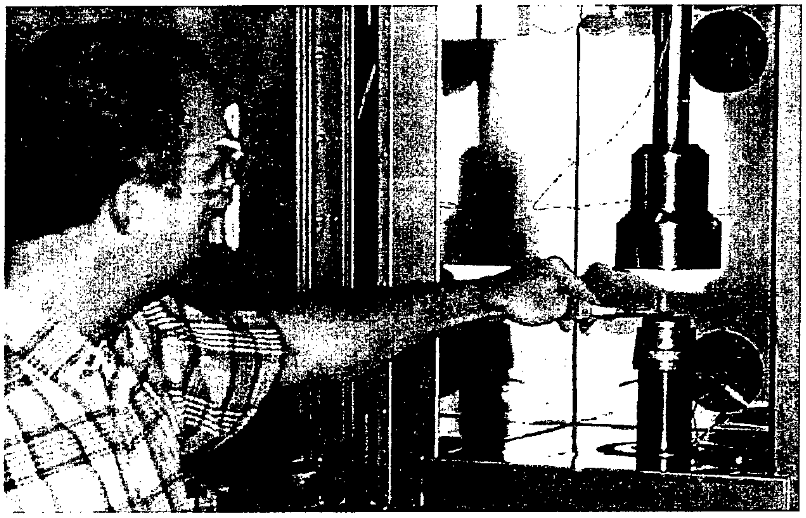

Figure 3. Energetic material prepared for testing on the MTS load frame.

Table 1. Mechanical properties of EX99 gun propellants at 21°, 50°, and –20 °C.

Lot	Stress at Failure (MPa)	Strain at Failure (%)	Modulus (GPa)	Failure Modulus[a] (GPa)	IED[b] (MPa)	FAV[c]
at 21 °C						
IH94X990088	98.1	4.40	1.940	–0.320	16.60	8A
LotIH23X99FB01	56.10	7.20	0.590	–0.310	8.30	8A
at –20 °C						
IH94X990088	128.0	5.40	2.54	–2.85	7.13	9A
LotIH23X99FB01	108.1	5.25	2.30	–1.90	5.56	9A
at 50 °C						
IH94X990088	59.19	5.10	1.19	–0.120	11.9	7A
LotIH23X99FB01	67.33	8.40	0.700	–0.230	11.8	7A

[a]The failure modulus (slope of the curve after failure) has been added. Generally, the lower the value, the worse the material (i.e., negative value indicates the material is unable to sustain load). A positive value indicates a positive failure slope (i.e., the material is better able to support load after failure).

[b]The IED (incremental energy density) value reported is the amount of energy per unit volume absorbed at 25% strain; this includes a portion of the area located beneath the stress/strain curve.

[c]The tested specimens were assigned a fracture assessment value (FAV). The values range from 0 (no observed fracturing) through 9 (severe fracturing observed). The type of fracture was also characterized using the following methodology: A = axial fracture, S = shear fracture, B = barreling/deformation, R = radial splitting (i.e., 9A indicates the tested specimens showed a severe amount of axial fracture).

At 21 °C, the mechanical properties of the EX99 propellants were very poor. Note the compressive and failure modulus values, which indicate the material provided brittle response and was unable to sustaining loads past about 10% strain. When comparing these values with the propellant lot contained in the Appendix, it becomes clearer the large difference in compressive and failure modulus. Also, the tested specimens at 21 °C (Figure 2) showed severe axial fracture.

At 50 °C, again the stress at failure, compressive, and failure modulus values indicate how brittle the material was. Axial fracture at 50 °C usually does not occur and is atypical in most gun propellants, i.e., JA2, M30, Appendix lot, etc. The tested specimens at 50 °C again showed moderate-to-severe fracturing of the materials.

At –20 °C, the tested specimens (Figure 4) from both lots of EX99 suffered severe axial and shear fracture damage that would have likely caused significant increases in the surface area of this material. The stress/strain plots (Figure 5) for the materials also correlate with the physical damage observed. Note the sharp stress vs. strain pulse for the lot that indicates the material had likely glass transitioned as a result of the –20 °C exposure. The highly negative failure modulus values also indicated the material's inability to sustain load at –20 °C beyond about 5% strain.

Overall, the EX99 7-perforated gun propellants showed very poor mechanical properties at 21°, 50°, and –20 °C when compared with the Appendix lot. The EX99 test results indicated both lots were sensitive to the uniaxial compressive testing, becoming "brittle" at 21° and –20 °C, and suffering prolific fracture. It should also be noted that the grains received by ARL from lot FB01 contained ~25% specimens with irregular perforation patterns while none of these flawed specimens were tested for mechanical response. Also, the scanning electron micrographs shown in Figure A-3 clearly show a lower level of binder-filler interaction in lot FB01 as compared to lot 0088. The fracture in the 0088 lot proceeds only through the binder, whereas the fracture in the FB01 lot takes advantage of the lower binder-filler interaction and proceeds by jumping from particle to particle. In this process, the cyclotrimethylenetrinitramine (RDX) is exposed and fractured. This may explain the lower stress levels achieved for lot FB01 at 21° and –20 °C (Figure 5) as compared to lot FB01. (Note: The nature of the fracture of the specimen during specimen preparation indicated that there was residual stresses in both propellant lots. The fracture, which was initiated across the center of the grain ran quickly to the outside edge. This is caused by residual stresses within the grain directing the crack to the outside because of a nonuniform internal stress field.) When comparing the two lots tested, lot 0088 had significantly better properties at lower temperature. However, both lots demonstrated very brittle responses.

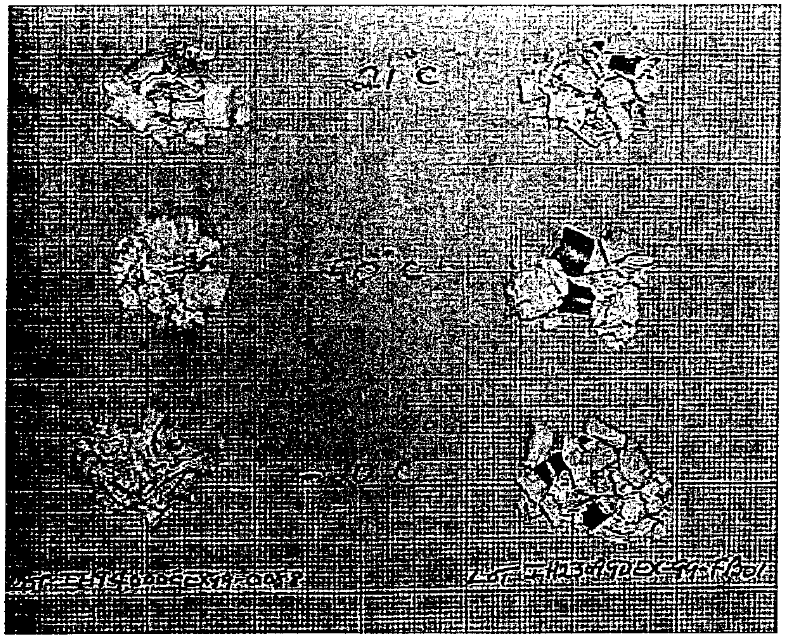

Figure 4. Tested specimens at 50°, 21°, and –20 °C.

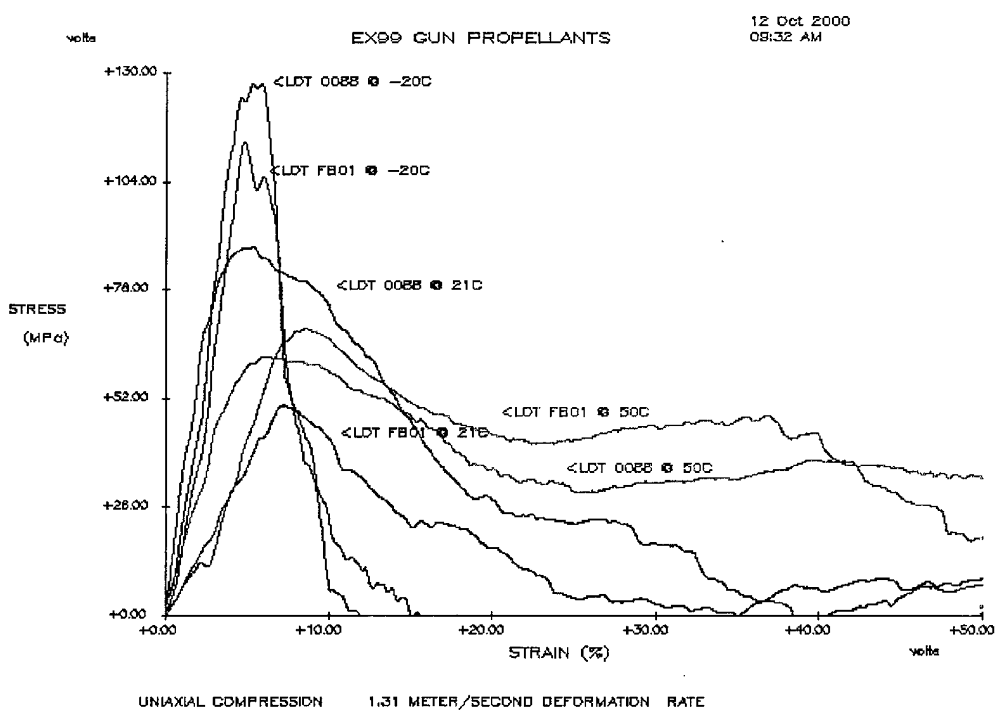

Figure 5. Stress vs. strain plot at 21°, 50°, and –20 °C.

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5. References

1. Gazonas, G. A. "The Mechanical Response of M30, XM39, and JA2 Propellants at Strain Rates From 10-2 to 250 Sec-1." BRL-TR-3181, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, January 1991.

2. Lieb, R. J. "Impact-Generated Surface Area in Gun Propellant." BRL-TR-2946, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, November 1988.

3. Lieb, R. J., and J. J. Rocchio. "High Strain Rate Mechanical Properties Testing on Lots of Solid Gun Propellant With Deviant Interior Ballistic Performance." *1982 JANNAF Structures and Mechanical Behavior Subcommittee Meeting*, CPIA Publication 368, pp. 23–38, October 1982.

4. Leadore, M. G. "MTS Servo-Hydraulic Tester (SHT) Mechanical Properties Evaluation of M43 Propellants." ARL-TN-5, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, March 1993.

5. Leadore, M. G., and C. J. Gillich. "Material Testing System (MTS) Servo-Hydraulic Tester (SHT) Mechanical Response of Energetic Thermal Plastic Elastomer (ETPE) RDX Based Propellants." ARL-TN-28, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, April 1994.

6. Leadore, M. G. "Mechanical Response of Energetic Thermoplastic Elastomer Low-Vulnerability Ammunition (ETPE-LOVA) RDX-Based, TNAZ-Based, and CL-20-Based Gun Propellants." ARL-TN-64, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, March 1996.

7. Lieb, R. J. Personal communication. "TGD-019 Lot M56-4-001 Customer Technology Transfer Report," October 2000.

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Appendix. Thermoplastic Elastomer Response

Table A-1. Mechanical properties of BAMO/GAP/RDX (TGD-019 lot M56-4-001) next-generation high-energy gun propellant (solid stick).

Lot	Stress at Failure (MPa)	Strain at Failure (%)	Modulus (GPa)	Failure Modulus (GPa)	IED (MPa)	FAV
at 21 °C						
M56-4-001	31.1	9.40	0.460	0.013	15.16	1B
at –20 °C						
M56-4-001	97.09	4.82	2.59	0.71	11.12	7AS
at 50 °C						
M56-4-001	16.5	8.82	0.27	0.009	6.11	1B

[a]The failure modulus (slope of the curve after failure) has been added. Generally, the lower the value, the worse the material (i.e., negative value indicates the material is unable to sustain load). A positive value indicates a positive failure slope (i.e., the material is better able to support load after failure).

[b]The IED (incremental energy density) value reported is the amount of energy per unit volume absorbed at 25% strain, this includes a portion of the area located beneath the stress/strain curve.

[c]The tested specimens were assigned a fracture assessment value (FAV). The values range from 0 (no observed fracturing) through 9 (severe fracturing observed). The type of fracture was also characterized using the following methodology: A = axial fracture, S = shear fracture, B = barreling/deformation, R = radial splitting (i.e., 9A indicates the tested specimens showed a severe amount of axial fracture).

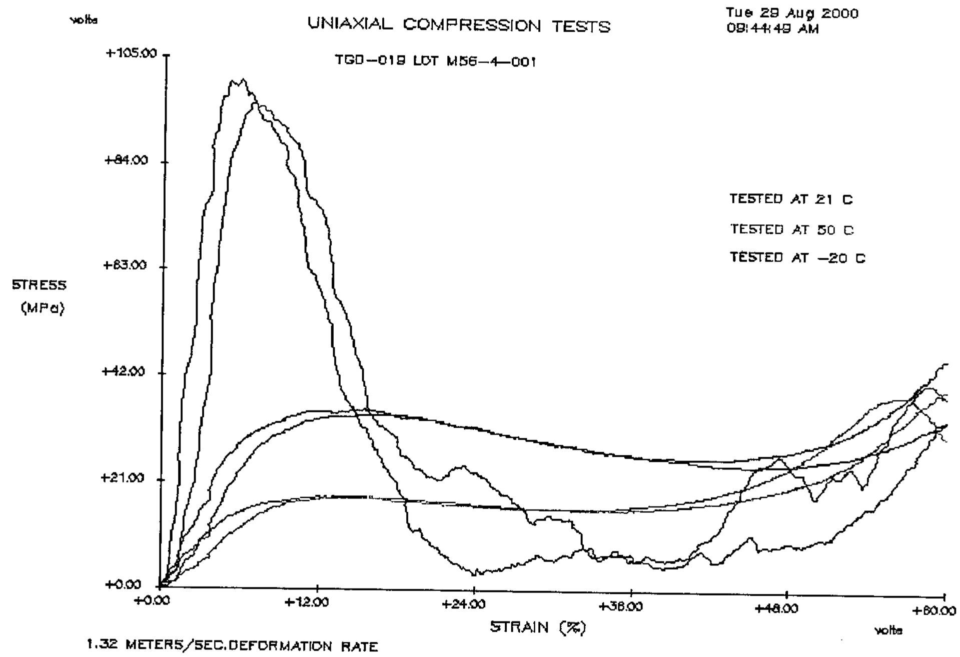
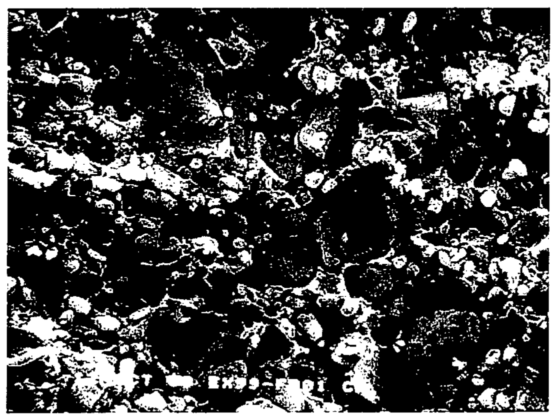


Figure A-1. Stress vs. strain plot for TGD-019 lot M56-4-001 next-generation high-energy gun propellant.

Figure A-2. Photograph of tested material from lot TGD-019.

(a) Lot 0088 at 750×



(b) Lot FB01 at 750×

Figure A-3. SEM micrographs of the EX99 propellants showing the difference in binder filler interaction.

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Two lots of EX99 gun propellants from the Naval Surface Warfare Center (NSWC) were tested in uniaxial compression to an end strain of ~60%. The materials were preconditioned at test temperatures of 21°, 50°, and -20 °C while at ambient pressure. The stress at failure, strain at failure, compressive modulus, failure modulus, incremental energy density (IED), and the fracture assessment values (FAV) were recorded for each test. These materials were also evaluated for microstructure using a scanning electron microscope (SEM).

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